METHOD FOR FORMING CVD FILM

FIELD OF THE INVENTION

The present invention relates to a method for forming a CVD film in the field of a semiconductor manufacturing process, such as a silicone oxide film, silicone nitride film, metal oxide film or metal nitride film.

PRIOR ARTS

In this technical field, a CVD film is formed in a vacuum process chamber at a constant reduced pressure. When the process gases are supplied, a pressure control valve (APC: Auto Pressure Control) which is disposed between the process chamber and a vacuum pump is operated to control the pressure constant at a vacuum. General features of the conventional process chamber are shown in Fig. 3.

The process chamber 4 has a gate valve 9, exhaust ports 11,11 and a shower head 10, mounted on an upper part of the process chamber 4 facing the substrate (object to be processed), through which process gases are supplied and a high radio frequency is applied to the substrate. The pressure inside the process chamber is controlled by the pressure control valve (not shown) by constantly exhausting the inside gas from the process chamber through the exhaust ports 11,11.

Fig. 6 shows a process flow chart indicating a CVD film formation process of the prior art. As shown, as first step 601, a substrate is placed on a stage (susceptor) provided in a process chamber, next at step 602, the pressure in the process chamber is reduced to a predetermined level. At 603, a process gas is supplied by applying a plasma, and at step 604, the gaseous

material is deposited on the substrate surface while the process gas is continuously supplied.

Then at step 605, a process gas for oxidizing or nitrifying is supplied. The important point in steps 603 to 605 of the CVD film formation process and oxidizing process, the pressure in the process chamber is always controlled at a constant reduced level by way of exhausting gases inside the chamber via the exhaust ports 11,11 by control of the pressure control valve.

After repeating several cycles of the above described steps 603 to 605, the gas supply is stopped and the plasma is turned off at step 606, and at 607, the substrate is taken out from the process chamber.

In the prior art mentioned above, the gas flows inside of the process chamber as the process chamber is exhausted constantly to maintain the pressure at the predetermined reduced level during the CVD film formation process. The flow rate of the gas is rather fast which causes a film formation rate difference between the center and the edge of the substrate (silicon wafer). Moreover, the film formation rate varies depending on the condition of the substrate surface, for instance, a step formed on the substrate surface changes the film formation rate.

In order to avoid the unpreferable effect of the gas flow inside the process chamber and to spray uniformly the process gas over the substrate surface, the shower head (10 of Fig. 3) is disposed over the substrate, or many exhaust ports are formed around the substrate. However, it is difficult to prevent the effect of the gas flow inside the process chamber and there also occurs another problem of particle contamination from the shower head. Moreover, the prior art cannot be applicable to a

large diameter substrate or highly integrated semiconductor devices.

In the development of recent semiconductor devices in which the circuit is highly integrated and a wire size of the tip becomes very minute, it is difficult to obtain a good step coverage and uniform film surface and, furthermore, to obtain good film characteristics by the conventional method.

Recently, in the film formation method by using a gas plasma, a high-density gas plasma is used for obtaining an excellent film. For example, to generate a high-density plasma, ECR (Electron-Cycrotoron-Resonannce), TCP (Transformer-Coupled-Plasma), or Helicon are proposed. However, they do not have a gas ejecting means like a shower head facing the substrate to be processed in a process chamber and the nozzles are arranged along the periphery of the upper part of the process chamber to supply a gas uniformly to the substrate to be processed. It takes a long time to design a proper arrangement of the nozzles depending on the inside pressure, gas flow rate and plasma source for the film forming process.

SUMMARY OF THE INVENTION

An objective of the present invention is to provide a novel method for forming a uniform CVD film which has good step coverage, uniform thickness and high quality characteristics.

The present invention provides a method and an apparatus for forming a uniform thickness CVD film with a high quality, in which at the material gas supply step, the process chamber is closed by closing a pressure control valve between the process chamber and the exhaust port, and even after stopping the process gas supply,

deposition on a substrate progresses in a process chamber under a pressure equilibrium condition. Successively, in the same process chamber, a gas for oxidizing or nitrifying is supplied with plasma application on the substrate to oxidize or nitrify the film on the surface of the substrate. By repeating several cycles of these steps (procedures), or a one cycle treatment, a uniform predetermined thickness film is obtained.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic plan view of a process chamber of the present invention for forming a CVD film by applying helicon plasma.

Fig. 2. is a sectional view of the process chamber of Fig. 1.

Fig. 3 is a sectional view of a prior art process chamber having a shower head.

Fig. 4 is a process flow chart of embodiment 1 of this invention.

Fig. 5 is a process flow chart of embodiment 2 of this invention.

Fig. 6 is a process flow chart of the prior art for producing CVD film.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig. 1 is a schematic plan view of a process chamber of the present invention for forming a CVD film by applying a helicon plasma and Fig. 2 is a sectional view of the process chamber of Fig. 1.

In these figures, number 1 indicates an electromagnetic coil formed around the high frequency antenna (not shown) for generating a helicon wave, which is placed at a top of a dome type high-frequency transparent quartz belljar 2 (process chamber). Gas

supplying nozzles 3 are disposed at a lower part of the quartz belljar 2, from which an oxygen gas, nitrogen or ammonium gas is supplied inside the belljar 2 to form a film. A gas-introducing pipe connected to the nozzles 3 is not shown.

Number 4 indicates a process chamber, and as shown in Fig. 1,5 is process gas-supplying nozzles which are arranged equidistantly around the circumference of the belljar 2. In Fig. 2, a plurality of nozzles 5 are illustrated as having an angle with respect to the substrate to be processed and there are numerous variations as to the number of nozzles and angle of the nozzles, unless the nozzles 5 are not affected by the gas plasma. A heater stage 6 is provided inside the process chamber 2 on which the substrate (semiconductor wafer) is heated.

A large diameter pressure control gate valve 7 has a pressure control means and is able to close the exhaustion port from the vacuum pump disposed under the pressure control gate valve 7. There is provided a turbo molecular pump 8 which reduces the pressure of the process chamber to a vacuum. A gate valve 9 for opening the process chamber to handle the substrate (wafer) is connected to a load-lock chamber (not shown).

A plasma source of a helicon wave for a CVD film-forming apparatus, generates helicon waves (whistler waves) by a helicon wave antenna and an electromagnetic coil 1, and a high-density plasma having a density of $10E11{\sim}10E13/cm^3$ is generated.

In general, the plasma density of the conventional plasma generating apparatus of the parallel flat type is about $10E9/cm^3$, but in the plasma generating apparatus used in this embodiment, the plasma density is 2 to 4 orders larger than the conventional plasma generating

apparatus. The high-density plasma is transmitted along a magnetic field generated by the electromagnetic coil 1, and supplies high-density reactive species on the substrate with an ion impact. Thus, organic compounds on the stage 6 are disassociated and removed effectively compared with the method of a high thermal CVD film formation or parallel flat type plasma CVD film formation.

Figs. 4 and 5 show a process flow chart showing a CVD film forming process of the present invention.

Fig. 4 indicates a remarkable point of the present invention, that is, the process for forming CVD film is performed in a closed condition by closing a pressure control gate valve 7. By supplying a process gas to the process chamber 4, the internal pressure of the process chamber 4 rises during deposition process, and after the process gas supply is stopped, under pressurized condition, uniform deposition progresses over the steps of the surface of the substrate.

First, the substrate is introduced in the process chamber 4 at step 401 of Fig. 4 and the process chamber 4 pressure is reduced at step 402. When the process chamber 4 pressure is reduced to a predetermined degree, a pressure control gate valve 7 is closed at step 403. Next at step 404, a process gas is supplied into the process chamber 4 at the reduced pressure, then the pressure in the process chamber rises depending on the amount of gas introduced into the process chamber, and the deposition process 1 on the substrate surface proceeds in the closed condition.

At step 405, when the process gas supply is stopped, the pressure inside the process chamber is maintained constant, and the deposition process 2 proceeds during this step 405. Next at step 406, the pressure control

gate valve 7 is opened to reduce the internal pressure in the process chamber, and at step 407 a gas for oxidizing or nitrifying is supplied with a plasma in the process chamber. At step 408, the oxidizing gas or nitrifying gas supply is stopped and also the plasma application is stopped. Repeating several cycles of these steps (procedures), a uniform thickness film is formed on the substrate at step 409.

Fig. 5 shows a process flow chart showing another process of forming CVD film of the present invention. The difference from the process in Fig. 4 is that in the deposition process, the plasma is applied in the process chamber. In Fig. 5, the plasma is applied from the first step 504 with a process gas supply, and the rest of the procedures of Fig. 5 are the same as the process in Fig. 4. In both embodiments, the process chambers are not exhausted during the deposition process.

Referring to Fig. 5, a substrate is introduced in the process chamber 4 at step 501, the pressure in the process chamber 4 is reduced to a vacuum by exhausting the gas in the process chamber by the turbo-molecule pump 8 through the pressure control gate valve 7 at step 502. Then the pressure control gate valve 7 is closed at step 503 and a process gas is supplied to the process chamber 4 under a vacuum condition at step 504, consequently, the internal pressure in the process chamber 4 rises at step 504 and a plasma is applied simultaneously with the process gas supply so further deposition proceeds in a closed gas-plasma atmospheric condition at 505.

At step 506, the process gas supply is stopped, although the plasma is still applied continuously, so the internal pressure in the process chamber is kept at a constant level and still the deposition proceeds under a gas-plasma atmospheric condition. Next at step 507, the

pressure control gate valve 7 is opened to reduce the internal pressure in the process chamber 4, and at step 508, an oxidizing or nitrifying gas is supplied, at step 509, the oxidizing or nitrifying gas supply is stopped and also the plasma application is stopped.

Repeating several cycles of these steps from 502-509, a uniform thickness film is obtained at step 510. In this embodiment of Fig. 5, the plasma is applied continuously in the process chamber through the steps of 504~509.

In the present invention, it is easy to change the gas species or power of plasma, and capable of continuing the process in the same chamber.

A difference between the process of Fig. 4 and Fig. 5 is the duration time of plasma application and, in both processes, the process chambers are not at a vacuum during the deposition process.

During the deposition process under a gas plasma condition, the gas plasma stimulates the dissociation of organic materials and is capable of shortening the deposition process time and obtain an excellent film.

In either embodiment, it is difficult to manufacture a high quality CVD film only by process gas deposition, therefore, an oxidizing or nitrifying process accompanied by heating or plasma application after the deposition, which removes the impurities (organic matters), is preferred.